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SOIL SURFACE TEMPERATURES ON CUTOVERS IN SOUTHWEST OREGON

by

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ABSTRACT

Discusses soil temperatures one can expect on various micro and macro sites in southwest Oregon. Gives recommendations for harvest techniques on steep southerly slopes.

High soil surface temperatures are commonly recognized as a cause of conifer seedling mortality. Silen[1/] has shown that soil surface temperatures lethal to Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings are common on cutover areas in the central Cascade Range of Oregon. Increased evaporation and transpiration due to high temperatures may also increase seedling mortality.

Heat as a factor in seedling mortality is a complex subject. Variation in survival of some seedlings and death of others continues to be perplexing. Silen has amply demonstrated that no single temperature can be considered lethal for Douglas-fir. Each seedbed type such as mineral soil or duff has a distinct killing temperature. Thus, seedlings might survive for hours under full exposure to sunlight in one seedbed and be killed in a few minutes on others. Even small amounts of shade at the base of a seedling stem are important to survival. Silen's studies showed no development of heat resistance

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[1/] Silen, R. R. Lethal surface temperatures and their interpretation for Douglas-fir. 170 pp. 1960. (Unpublished Ph.D. thesis on file at Oreg. State Univ., Corvallis.)

with age in a seedling. Keijzer and Hermann[2] did demonstrate that such resistance appeared to develop in explanation of variation found in the field.

Franklin[3] observed that rather large numbers of Douglas-fir seedlings in the central Cascades do survive after exposure to sunlight for many hours without stand-edge shade. Thus, it would appear from cited studies that it is not essential that every square foot of a clearcut be fully protected from excessive surface heat and that any substantial alleviation of midday heat problem may be enough to get minimum acceptable levels of stocking under southwestern Oregon conditions.

Simple exploratory studies reported here were conducted to help delineate the problem concerning heat and mortality of seedlings in southwestern Oregon.

METHODS

Influence of elevation, slope and aspect, low objects, timber edge, and time of day on soil surface temperatures was explored by use of commercial temperature pellets (Tempils).[4] Tempil melting points were 113°, 125°, 138°, 150°, 163°, 175°, and 188° Fahrenheit. At each sampling point, highest temperature attained was indicated in 12° or 13° intervals by a melted Tempil and was recorded as range in temperature. For example, 125°-138° indicates that maximum temperature was 125° or higher but less than 138°. Tempils were broken in half and inserted vertically in soil to assure that ground-line temperatures were recorded.

2/ Keijzer, Steven de, and Hermann, Richard K. Effect of environment on heat tolerance of Douglas-fir seedlings. Forest Sci. 12: 211-212. 1966.

3/ Franklin, Jerry F. Natural regeneration of Douglas-fir and associated species using modified clearcutting systems in the Oregon Cascades. U.S. Forest Serv. Res. Pap. *PNW-3*, 14 pp., illus. 1963.

4/ Silen, Roy R. Use of temperature pellets in regeneration research. J. Forest. 54: 311-312., illus. 1956.

Elevation.--Temperatures were measured (August 1964) in the upper South Umpqua drainage at 10 locations ranging from 1,850 to 5,000 feet in elevation (elevations from U.S. Geological Survey maps). Tempils were placed in boxes of fine, light-colored, beach sand at each location. Sand was used in order to eliminate variation in heating rate that might occur in the soils at the sampling location. Sand boxes were placed on level, unshaded spots with sand surface flush with natural ground surface. At four locations, Tempils were also placed in unshaded mineral soil near the sand boxes.

Slope and aspect.--Temperatures were measured (August 1964) at the surface of inclined boxes of soil on a level area at the Pacific Northwest Forest and Range Experiment Station's Roseburg laboratory site. River loam, sifted through a 20-mesh screen, was placed in conventional greenhouse flats and compacted by wetting. When the soil appeared dry, pairs of boxes were installed on inclined frames with 25-percent, 50-percent, 75-percent, and 100-percent slopes. One of each pair faced due north and the other due south. In addition, two boxes were placed with no slope--one box on the ground and the other set on a light, wood frame approximately 1 foot above soil surface. Two sets of Tempils were inserted in each box.

Shade from low objects.--Soil surface temperatures in a clearcut were measured (June and July 1962) near low objects on a steep (60-70 percent) west slope (10^{o} south of west). Microsites, sampled with two replications each, were unshaded bare ground, north and south side of logs, north side of shingles approximately 3 inches wide, under grass, and at base of deerbrush (*Ceanothus integerrimus*) approximately 2 feet high and 2 feet across.

Timber edge.--Soil surface temperatures were measured (summer 1964) along four lines at right angles to an east and west edge of the clear-cut. Strips were approximately 1 chain apart. Tempils were placed at ½, 1, 2, 3, 4, and 5 chains north of the timber edge in bare mineral soil. All objects, other than trees, that would shade the Tempil locations were removed. Ground sloped gently east and northeast.

Time of shade.--On July 29, 1965, effect of shade duration on surface temperature was measured on a level area at the Roseburg laboratory site. Shade was provided with grocery packing cartons approximately 12 to 18 inches on a side. A small hole at the bottom of the south side and the entire north side of each carton was cut out to provide for air circulation. Tempils were placed in dry river loam soil in cigar boxes under the cartons. Cartons were systematically removed to expose the Tempils for all multiples of 2 hours for the period 0700 to 1700 (true or solar time), starting with the period 0700 to 0900. Thus, cumulative temperature records were taken for 15 different 2-hour, or multiple of 2-hour, periods that soil was exposed to full sunlight.

Shadow length and direction.--Length and direction of shadows were computed from astronomical formula and data for June 21 at 42°30' latitude for each hour of solar time from 0700 to 1700. Shadow distance at right angle to timber edges and percentage of surface of clearcut strips of different widths were also computed.

RESULTS

Temperatures reported here are maximum with no measure of the time they persisted. Where a range is given, temperature was above the lower value and below the higher value.

Elevation.--In the period July 23 to September 1, 1964, elevation had no effect on maximum surface temperature of sand in small boxes set in the ground at elevations of 1,850 to 5,000 feet, as recorded with Tempils. During the period July 23 to July 30, maximum observed surface temperatures were either slightly below or slightly above 138° F. Temperatures above and below 138° F. were observed over the complete range of elevations sampled. During the period August 18 to September 1, maximum surface temperatures at all sampling points were between 125° and 138° F. Maximum surface temperature of unshaded mineral soil was the same as for sand.

Slope and aspect.--As expected, maximum soil surface temperatures increased as slope percent increased on south aspects and decreased as slope percent increased on north aspects (fig. 1). During the period August 5 through August 24, 1964, maximum surface temperatures on inclined boxes of soil were as follows:

Slope (Percent)	Aspect	Maximum temperature (Degrees F.)
100	North	Less than 113
75	North	125 - 138 1/
50	North	125 - 138
25	North	125 - 138
0	-	125 - 138 2/
25	South	138 - 150
50	South	138 - 150
75	South	150 - 163
100	South	150 - 163

1/ Condition of Tempils suggested that temperature was closer to 125° than 138°. In this case, most of the 125° F. pellet remained unmelted.

2/ Condition of Tempils suggested that temperature was closer to 138° than 125°. In this case, all the 125° F. pellet had melted.

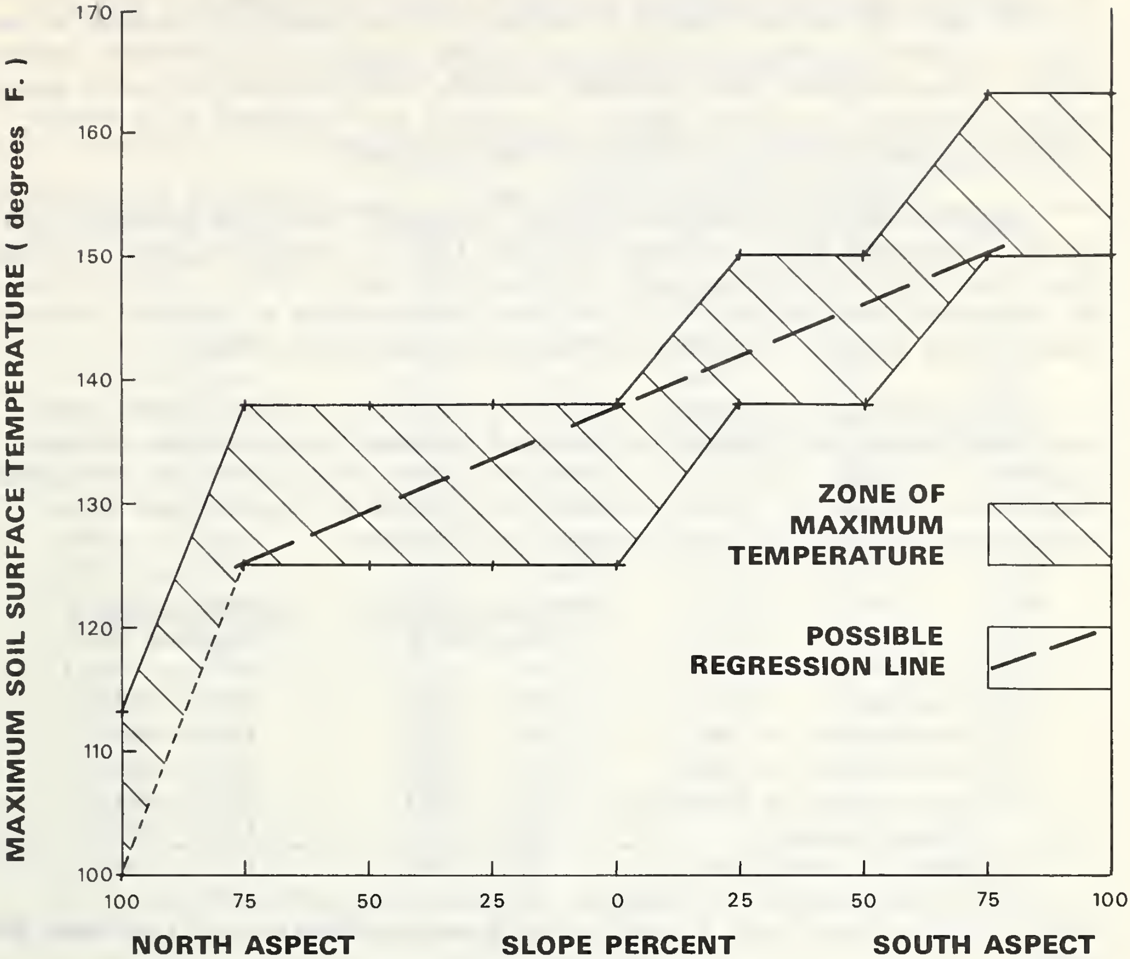

Figure 1.--Influence of slope and aspect of inclined boxes of river loam on maximum soil surface temperatures August 5 to August 25, 1964.

On figure 1, an approximate regression line indicating a change of 1.7° F. per 10-percent change in slope can be drawn in the zone of maximum temperature between 75-percent north slope and 75-percent south slope. Data suggest that maximum surface temperatures on south aspects become constant at slopes above 75 percent but decrease at a faster rate on slopes above 75 percent on north aspects.

Maximum surface temperatures on the level soil box raised 1 foot above the ground were between 125° and 138° F., whereas those on the box flush with the ground were between 138° and 150° F. Therefore, it is probable that maximum soil surface temperatures on natural ground slopes were higher than those observed on inclined boxes.

Shade from low objects.--On steep westerly slopes, shade from logs, shingles, and vegetation reduced maximum temperatures on soil surfaces, but not below 138° F. except under deerbrush. In the period June 26 to August 1, 1962, maximum soil surface temperatures on a steep westerly facing clearcut were as follows:

	Sample point 1 (Degrees F.)	Sample point 2 (Degrees F.)
Unshaded	163 - 175	175 - 188
South side of log	163 - 175	175 - 188
North side of log	138 - 150	150 - 163
North side of shingle	150 - 163	150 - 163
Under grass	163 - 175	175 - 188
Base of deerbrush	125 - 138	125 - 138

Soil surfaces were bare except under grass where grass litter was present.

East and west timber edge.--Shade from an east and west timber edge on the south side of a clearcut (July and August 1964) reduced maximum soil surface temperatures for a distance of less than 1 chain into the clearcut. Maximum surface temperatures at one-half chain were less than those at 1 chain for 14 out of 17 observations. At 1 chain and beyond, temperatures were essentially the same. During midday, 1/2-chain points were always shaded, whereas points 1 chain and beyond were never shaded. Average height of dominant trees along or near the timber edge was 140 feet.

Time of shade.--Among combinations of full exposure for various periods, shading soil surfaces before 1100 and after 1500 had little effect on maximum temperatures (table 1). In all cases where soil was exposed to full sunlight from 1100 to 1500, maximum surface temperature was between 138° and 150°, regardless of whether or not surface was exposed to full sunlight before 1100 or after 1500. The period 1100 to 1300 was most important for attaining maximum temperatures, as sun between 1300 and 1500 increased maximum temperature only a few degrees.

Table 1.--*Effect of time of day and duration of full sunlight on river loam soil surface temperatures*[1/]

Duration of exposure to full sunlight	Temperature rating by Tempil melting points[2/] at designated solar times				
	0900	1100	1300	1500	1700
	- - - - - - - - - -	- -	Degrees F.	- -	- - - - - - - - -
0700 to 1700	<113	125S	138S	138M	138M
0700 to 0900	<113	<113	<113	<113	<113
0700 to 1100	<113	125S	(3/)	(3/)	125M
0700 to 1300	<113	125S	138S	(3/)	138S
0700 to 1500	<113	125S	138S	138M	138M
0900 to 1100	<113	125S	(3/)	(3/)	125M
0900 to 1300	<113	125S	138S	(3/)	138S
0900 to 1500	<113	125S	138S	138M	138M
0900 to 1700	<113	125S	138S	138M	138M
1100 to 1300	(3/)	<113	138S	(3/)	138S
1100 to 1500	(3/)	<113	138S	138M	138M
1100 to 1700	(3/)	<113	125G[4/]	138S	138S
1300 to 1500	(3/)	(3/)	<113	125G	125G
1300 to 1700	(3/)	(3/)	<113	125G	125G
1500 to 1700	(3/)	(3/)	(3/)	<113	113M

1/ July 29, 1965, at Roseburg--maximum air temperature, 93° F. All time is true or solar time.

2/ S, pellet slightly melted; M, approximately one-third to one-half melted; G, pellet completely melted.

3/ No reading.

4/ Partial shade from windblown box.

Shadow length and direction.--Computations show that clearcut strips or patches must be quite narrow if an appreciable percentage of the soil surface is to be shaded during hot midday periods.

Shadow length (fig. 2, table 2) as percent of tree height and direction were computed for different hours from following formulas:

1. Sine a = cosine d x sine H x cosine L + sine L x sine d

2. Cosine z = tangent a x tangent L - $\dfrac{\text{sine } d}{\text{cosine } a \text{ x cosine } L}$

3. $\frac{S}{h} \times 100 = \text{cotangent } a \times 100$

where:

a = angle of sun's altitude

d = sun's declination as determined from a solar ephemeris

L = latitude

H = sun's hour angle measured from 0600 solar time (15^{o} per hour)

z = sun's bearing measured from south

S = shadow length cast by border trees

h = height of border trees

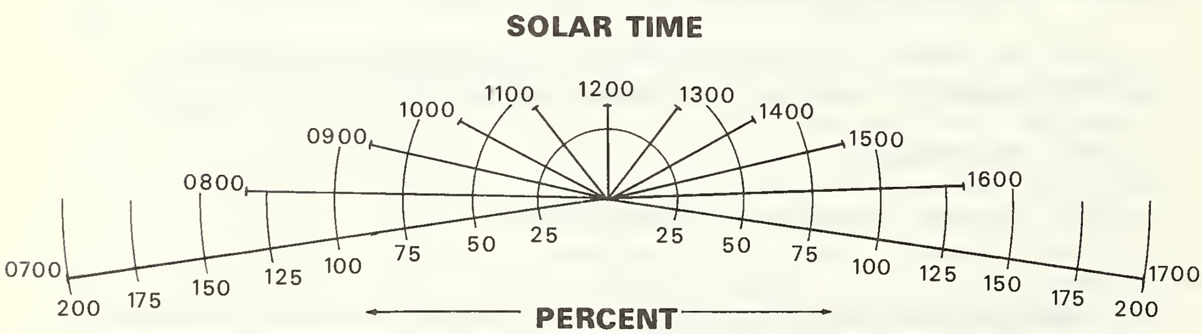

Figure 2.--Shadow direction and length as percent of tree height; June 21, lat. 42°30'.

Table 2.--*Relative length and direction of tree shadows, June 21, latitude 42°30'*

Sun time	Bearing from north	Length as percent of tree height
0700	98°28' W.	201.9
0800	88°48' W.	130.9
0900	77°25' W.	89.0
1000	62°03' W.	60.8
1100	37°52' W.	41.9
1200	0°	34.5
1300	37°52' E.	41.9
1400	62°03' E.	60.8
1500	77°25' E.	89.0
1600	88°48' E.	130.9
1700	98°28' E.	201.9

Shadow distances at right angles to timber edges running NW.-SE., NE.-SW., N.-S., and E.-W. were computed from shadow length and direction and sun's angle to timber edge for various hours of the day (fig. 3). Computations were made for June 21, the day with the shortest shadows, and for latitude 42°30', approximate midlatitude for the mixed pine-fir type in southwestern Oregon. Shadows for a 100-foot tree are only 3 feet longer at noon on June 1 and July 12 than on June 21; hence, there is a 40-day period when changes in shadow length are small.

With data on shadow distance measured at right angles to cutting edge, percentage of clearcut strips shaded was computed for hourly intervals from 0700 to 1700 (figs. 4, 5, 6, 7; table 3). Area shaded at ends of strips was ignored because the purpose is to show effect of strip width. Strip widths equal to 50 percent, 100 percent, and 200 percent of border-tree heights were used.

Average effective tree height for shading clearcuts is less than average height of dominant trees because of undulating level of the crown canopy along a timber edge. Average effective tree height for casting shadows from timber edges also varies with density of the remaining stand along timber edge. The minimum reduction from actual average tree height that should be used is probably 10 feet.

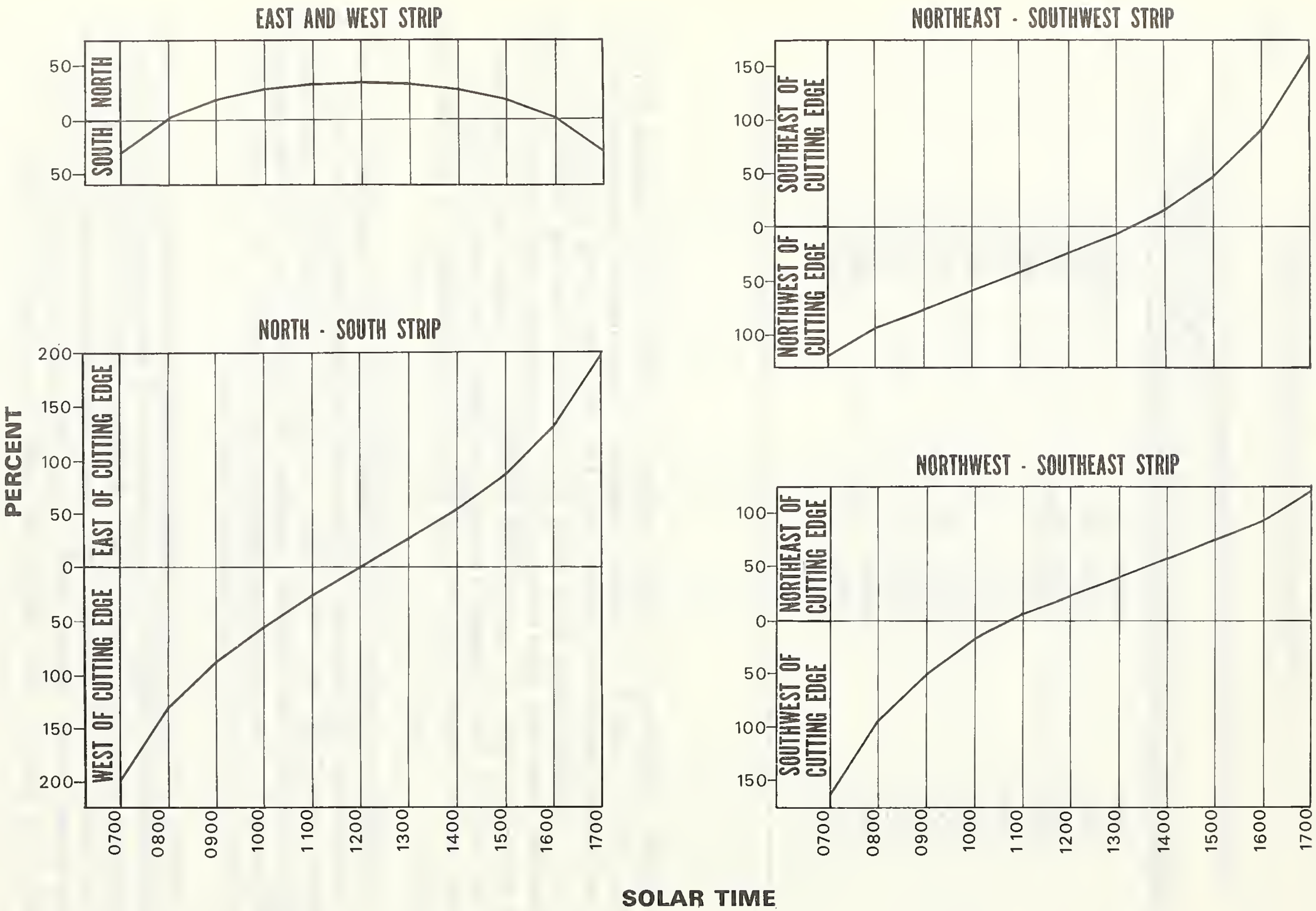

Figure 3.--Shadow distance at right angle to timber edges as percent of border tree height, by time of day, June 21, lat. 42°30'.

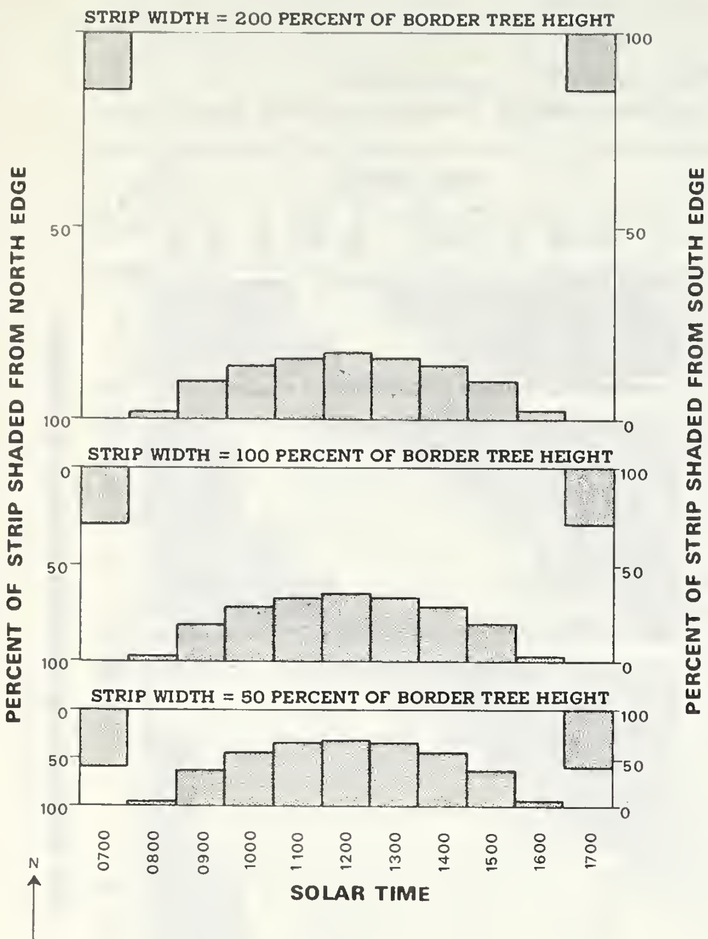

Figure 4.--Percent clearcut strip width shaded. East-west strip, June 21, lat. 42°30'.

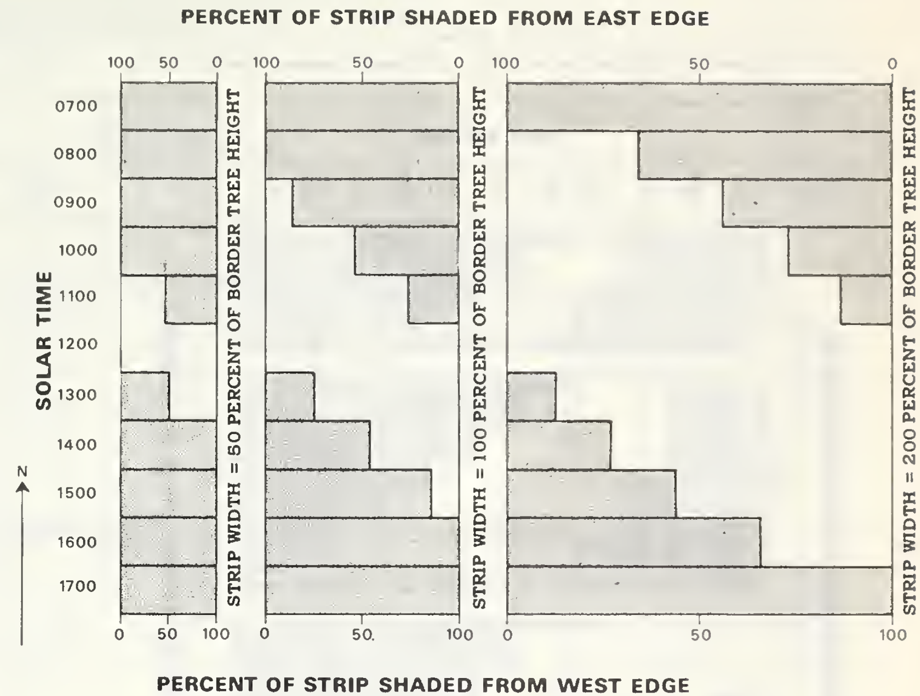

Figure 5.--Percent clearcut strip width shaded. North-south strip, June 21, lat. 42°30'.

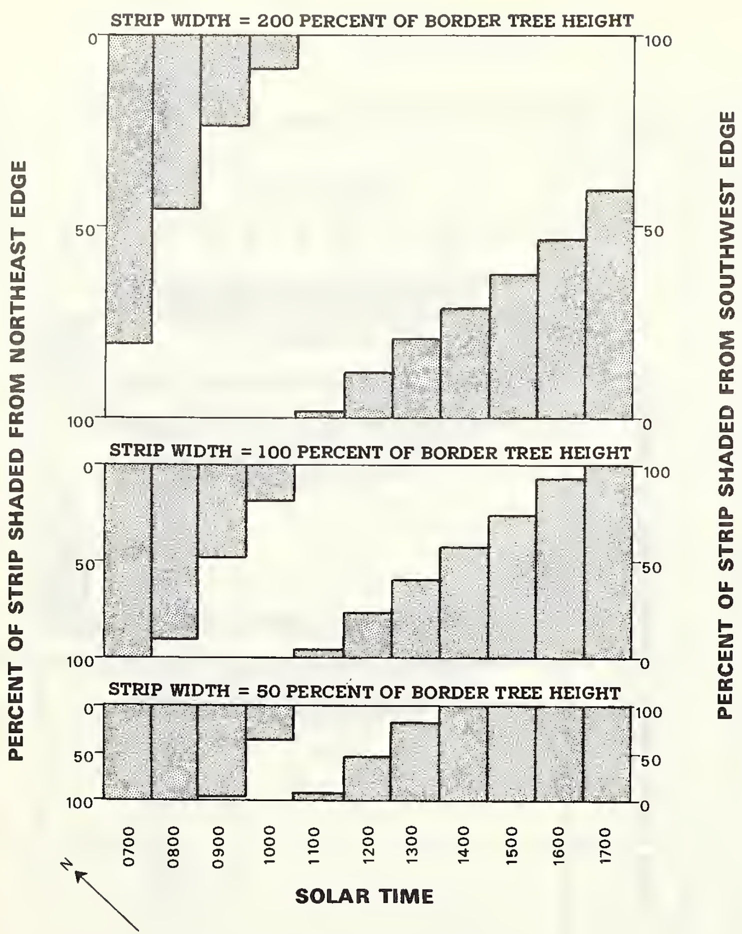

Figure 6.--Percent clearcut strip width shaded. Northwest-southeast strips, June 21, lat. 42°30'.

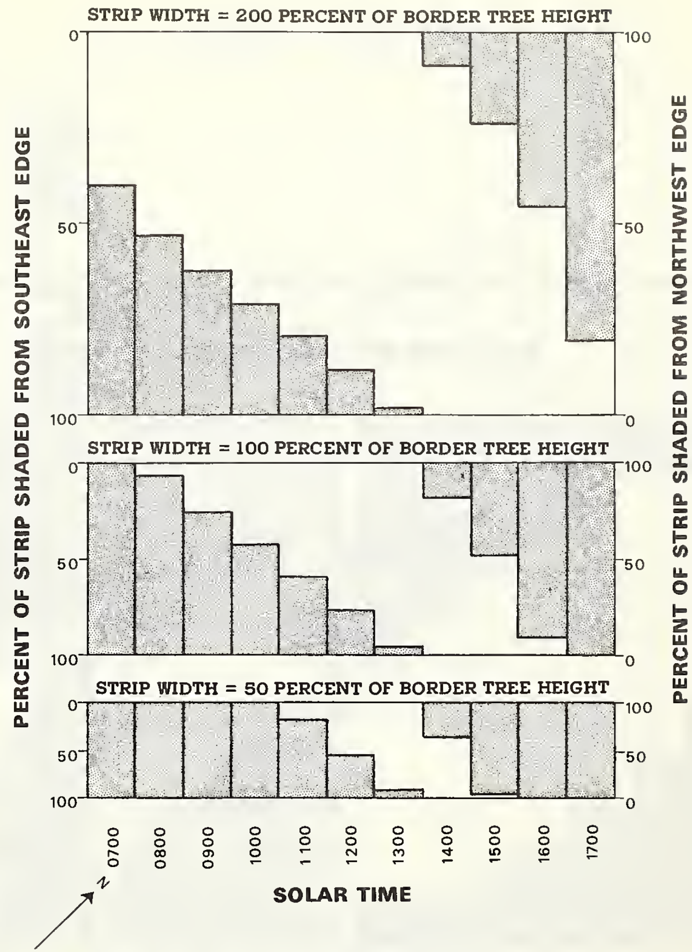

Figure 7.--Percent clearcut strip width shaded. Northeast-southwest strips, June 21, lat. 42°30'.

Table 3.--*Percent of clearcut strip width shaded by time of day and by strip direction, for strips of three relative widths, June 21, lat. 42°30'*

Strip direction	Solar time										
	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700
	Strip width equal to 50 percent of border tree height										
NW.-SE.	100	100	96	36	10	48	84	100	100	100	100
NE.-SW.	100	100	100	100	84	48	10	36	96	100	100
N.-S.	100	100	100	100	52	0	52	100	100	100	100
E.-W.	60	6	38	56	66	68	66	56	38	6	60
	Strip width equal to 100 percent of border tree height										
NW.-SE.	100	91	48	18	5	24	42	58	75	94	100
NE.-SW.	100	94	75	58	42	24	5	18	48	91	100
N.-S.	100	100	87	54	26	0	26	54	87	100	100
E.-W.	30	3	19	28	33	34	33	28	19	3	30
	Strip width equal to 200 percent of border tree height										
NW.-SE.	81	46	24	9	2	12	21	29	38	47	60
NE.-SW.	60	47	38	29	21	12	2	9	24	46	81
N.-S.	100	66	44	27	13	0	13	27	44	66	100
E.-W.	15	2	10	14	16	17	16	14	10	2	15

When strip width equals 50 percent of border tree height, none of north-south and only 16 percent of northwest-southeast clearcut strips are exposed to full sunlight for 2 hours or more during the critical period 1100 to 1500 (table 4).

Table 4.--*Percent of width of clearcut strips exposed to full sunlight 2 hours or more during period 1100 to 1500, June 21, lat. 42°30'*

Strip direction	Strip width as percent of border tree height		
	50	100	200
North-south	0	74	87
Northwest-southeast	16	58	79
East-west	34	67	83
Northeast-southwest	80	95	97

DISCUSSION AND CONCLUSIONS

Exploratory studies for southwest Oregon, reported in this paper, are backed up by cited studies in the Cascade Range of Oregon and bring out a consistent picture. Southwest Oregon situations appear to be somewhat more extreme in that higher maximum temperatures were found than in other studies. For example, 175° F. recorded in southwest Oregon was higher than the highest temperature found by Silen in the Oregon Cascades. Hence, general conclusions for the Pacific Northwest region, regarding need for reduction of surface temperatures, are more acute in southwest Oregon.

Interplay of several factors must be kept in mind in developing any recommended practice for reduction of seedling mortality from high surface temperatures. Silen[5/] has shown that lethal seedbed surface temperatures vary with duration and kind of seedbed surface. For example, more than 4 hours of exposure to 130° F. are required to kill in most easily heated seedbeds. At 150° F., on the other hand, about 15 minutes of exposure are required to kill in a litter type of seedbed characterized by peat moss, whereas seedlings survive about 1 hour in yellow mineral soil. At 138° F., the temperature used in this paper to characterize

[5/] See footnote 1.

mortality, the corresponding durations of exposure for mortality are about 1 hour in peat moss and 4 hours in yellow mineral soil. Thus, it becomes apparent that more extreme temperature conditions in southwest Oregon make need for shade more critical.

Another factor is that natural variation on clearcuts appears to provide a percentage of microsites that never reach lethal temperatures. The proportion is small on south slopes but rises on more favorable northerly aspects.

Within this general framework, results of exploratory studies reported here suggest some tentative recommendations for southwest Oregon.

In the South Umpqua drainage, maximum summer temperatures on unshaded soil surfaces normally are in excess of 138° F. On steep southwesterly slopes, maximum surface temperatures in excess of 175° F. have been measured and are usually considerably in excess of 138°. Data from inclined boxes and field measurements indicate that maximum surface temperatures on unshaded soil on level and north aspects commonly are not greatly in excess of 138°, and on steep north slopes may be less than 138°. Thus, shade from low objects like logs, chunks, or shingles won't reduce maximum soil temperatures below lethal levels on southerly and westerly aspects, but usually will on northerly slopes. Furthermore, under the same sun, shade from low objects on north slopes will cover a greater area than on south slopes. On southerly aspects, additional high shade is probably necessary in order to prevent heat-killing of new seedlings.

Shade may be necessary for establishment of natural regeneration at all elevations in the South Umpqua drainage, since maximum soil surface temperatures may exceed 138° F. at all elevations up to 5,000 feet.

On the basis of the 2-hour temperature measurements on level ground, it would appear that critical time to have full shade would be between 1100 and 1500. Temperatures of fully exposed level surfaces were only slightly above 125° F. up to 1100. Maximum temperatures between 138° and 150° were reached on all surfaces fully exposed between 1100 and 1500, regardless of whether or not they were shaded before 1100. Additional sunlight between 1300 and 1500 increased maximum temperatures only slightly over those already reached on areas exposed to sun between 1100 and 1300. However, shade between 1300 and 1500 is very important, as it will reduce duration of maximum temperatures.

An increase in temperature increases transpiration and, therefore, contributes to drought-caused mortality. Periods of shade at any time of the day may be helpful in reducing drought-caused mortality of planted trees, especially on southerly and westerly aspects.

Additional high shade to supplement low shade may be provided by partial or strip cutting. Partial cutting is now used quite extensively in southwest Oregon on areas where topography is suitable for tractor logging. Apparently, adequate shade for successful establishment of reproduction is being provided. However, with presently available logging equipment, it is not practical to make extensive partial cuts on steep slopes with low volumes of timber. Although strips can be logged with high lead on steep slopes, narrowness of strip needed for optimum shade prevents economical logging.

Data for shadow length and direction show that width of clearcut strips must not exceed approximately 50 percent of effective border-tree height to lower maximum soil surface temperatures and thus reduce killing of new seedlings.[6/] For example, regardless of orientation, over 50 percent of strip width is exposed to 2 hours or more of direct sunlight in the critical period 1100 to 1500 if strip width is equal to 100 percent of border-tree height. If strips are 50 percent of tree height, orientation in any direction except northeast and southwest is suitable (table 3). However, if north-south strips are used, cutting of adjacent strips must be delayed until the new crop of trees is tall enough to cast shade an effective distance. With east-and-west or northwest-southeast strips, midday shade comes from south or southwest sides. Consequently, the next strip can be cut as soon as regeneration is established on the first strip.

Width of strips needed to provide shade to prevent heat-killing of new seedlings varies with slope, aspect, and direction of strip as well as border-tree height. However, in southwestern Oregon, clearcut strip widths needed to provide adequate shade to prevent heat-killing of new seedlings usually will be approximately 1 chain or less, as tree height commonly is 150 feet or less on southerly aspects where heat-killing is critical. Thus, 50 percent of effective tree height is commonly 70 feet or less if effective tree height is 10 feet less than actual height. With presently available logging equipment, it usually is not practical to use strips as narrow as one chain in harvesting timber on steep southerly slopes.

[6/] In this discussion, unless otherwise specified, reference is made to level areas, June 21, and latitude 42°30'. Shadows from southerly timber edges are shorter on south slopes and longer on north slopes than on level ground.

RECOMMENDATIONS

The following recommendations for southwest Oregon are made for areas on which high surface temperatures are an important cause of seedling mortality:

1. Wherever tractor logging is suitable, harvest timber with a partial cut or with strips not wider than 50 percent of border-tree height, but avoid strips oriented northeast-southwest.

2. Hold to a minimum timber harvesting on southerly slopes too steep for tractor logging until equipment is developed that will permit economic logging of low volumes of timber on narrow strips or partial cuts.

3. Development of logging equipment that will permit economic harvesting of low volumes of timber on steep slopes for partial cuts or narrow strips should be expedited.

4. In the interim, whenever it is necessary to harvest timber on steep southerly slopes--

    a. Clearcut strips or units should be as narrow as practical.

    b. Northeast-southwest oriented strips or clearcut units should be avoided if possible.

    c. A lower standard of stocking and a longer regeneration period should be accepted.

    d. Wherever it is not essential to burn the slash, trees should be left standing in lanes radiating from the spar pole.